PATENT SPECIFICATION

916,144

Inventors: ALAN HENRY BUTLER, HARRY ALBERT COX and RAYMOND HICKS

Date of filing Complete Specification (under Section 3 (3) of the Patents Act 1949): April 29, 1960

Application Date: May 4, 1959. *No. 15211/59*

Application Date: July 8, 1959. *No. 23468/59*

Application Date: April 12, 1960. *No. 13037/60*

Complete Specification Published: January 23, 1963

Index at Acceptance:—Class 39(4), C4B5.

International Classification:—G21.

COMPLETE SPECIFICATION

DRAWINGS ATTACHED

Improvements in or relating to Heterogeneous Nuclear Reactors

WE, THE GENERAL ELECTRIC COMPANY LIMITED, of Glen House, Stag Place, Victoria, London, S.W.1., formerly of Magnet House, Kingsway, London, W.C.2., a British company, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to heterogeneous nuclear reactors and more particularly to moderator core structures therefor, of the kind in which the main core is composed of an assembly of lines of prismatic blocks of graphite arranged end to end, usually vertically or horizontally, some at least of the lines of blocks having holes therethrough which are aligned to form channels for the reception of fuel devices. The core itself will usually be arranged within reflector blocks, which may be similarly arranged in lines of blocks. On account of the assembled nature of the moderator it is necessary to provide restraining members for the structure, but it is usually not possible for the restraining members to be of the same material as the moderator. Difficulties then arise from the differential expansion between the moderating material and the restraining material. It is apparent from consideration of tables of physical constants that many moderating materials have smaller coefficients of thermal expansion than materials which can conveniently be used for the restraints, and this has meant that in moderator assemblies, hitherto, restraint which is effective at room temperature has been lost to a certain extent at operating temperatures of the core. Although special composite compensating restraint members have been proposed to take up this differential expansion, temperatures throughout the core will not be uniform, and in consequence it will be evident that it is almost impossible to achieve uniformity of restraint by this means. Moreover, in operation, due principally to irradiation effects, the individual blocks themselves may be susceptible to dimensional changes; for instance, in the case of a graphite moderator, the graphite will suffer so-called Wigner shrinkage. In addition, such changes will not be uniform over the whole of the core, and while this effect may not be of consequence in certain reactors, it is evident that where high temperatures of operation are concerned, the variation and difference of restraint would be serious.

The present invention is concerned with improving the supporting means for the core structure, an object of the invention being to provide a form of restraint which can be used to obviate the difficulties described above.

For an heterogeneous nuclear reactor of the kind comprising a core structure consisting of an assembly of blocks of moderating material, at least some of which blocks contain channels for the reception of fuel elements, said channels being substantially parallel to each other and to an axis of the core structure, restraining means for the core structure in accordance with the invention comprises a plurality of core-engaging assemblies spaced about the core, each said core-engaging assembly being adapted to exert a variable restraining force on said core structure in a direction substantially at right angles to said axis, and each said core-engaging assembly comprising a series of links between rollers or the like which are adapted alternately to engage the core structure, or means in contact with the core structure, and a support structure substantially surrounding said core structure, means being provided for exerting a force substantially

parallel to said axis to cause said link assemblies to exert a variable restraining force on said core structure substantially at right angles to, and substantially towards, said axis.

These core-engaging assemblies may comprise link and roller systems in doubled, lazy-tongs construction, as by this means the loading on individual rollers may be reduced without adding to the overall size of rollers;

In certain circumstances, where the linkage members are wholly in compression, there may be a tendency for the restraint system to become unstable, and it is a further object of the present invention to provide a version of restraint system which will not be susceptible to this tendency. Thus according to a feature of the present invention, the said force exerting means may be arranged to operate to exert a tensional force on its said link assembly, so as to induce a compressive force against said core structure. In the restraint system said core-engaging assemblies then are preferably arranged in pairs, each pair being adapted to react against substantially opposite sides of the core.

The said forces applied parallel to the axis, compressive or tensional, may be derived from a jack system under fluid pressure. Since it is desirable that leakage of said fluid under pressure which may enter the region of said core structure should not contaminate the structure, it is preferably arranged that said fluid is identical with fluid used to cool the fuel. If a gaseous fluid is used as coolant, such as carbon dioxide or helium, said jack system will then be gas-operated and will automatically be capable of permitting relative movement between said core structure and said supporting structure parallel to the axis and arising, for instance, from differential thermal expansion, since the gas will tend to be compressed still further under reverse movement of the jack caused by said axial movement.

Alternatively said jack system may be hydraulic and may be adapted by virtue of incompressibility of the fluid to withstand shock loading of the linkage system resulting from loads suddenly applied to the core structure, as for instance, loads induced by earthquake shock.

At the same time such an hydraulic system may be adapted, by a suitably arranged damper valve or like means, to permit bleeding of the fluid to permit of the aforesaid relatively slow thermal movement between core structure and supporting structure.

When the jack system is hydraulic for reason of shock resistance, the main system may be gaseous to overcome objections due to contamination referred to above, and said hydraulic system may be pressurised by said gaseous system whereby said hydraulic system acts as a follow-up to the gaseous system.

In order that the invention may be better understood, arrangements of restraint systems will now be described with reference to the drawings accompanying the provisional specifications. The restraint system shown in Figures 1, 2 and 3 (referred to in Application No. 23468/59) is for a horizontally disposed graphite core structure, but the adaptation of such a system to vertically or otherwise arranged core structures will be evident to those skilled in the art.

Figure 1 represents a half vertical section through the core structure within a pressure vessel; Figure 2 is a somewhat diagrammatic section on the line II-II of Figure 1; and Figure 3 is a diagrammatic representation of the effect of the link and roller arrangement illustrated in Figure 2.

Another embodiment of the invention, for vertically arranged constructions, is illustrated in the drawing accompanying the provisional specification in Application No. 13037/60. This figure is somewhat diagrammatic and shows a vertical section through one form of core structure.

Referring now to Figures 1, 2 and 3 of the drawings accompanying the provisional specification in Application No. 23468/59, the core structure comprises hexagonal blocks assembled into a core proper 1, (indicated within the thickened line), wherein the blocks are provided with channels for the reception of fuel or for the insertion of control rods. The core proper is surrounded by a reflector 2 composed also of hexagonal blocks in the main, but shaped at its outer faces as a smooth sided hexagonal prism. Two opposite edges of this prism are arranged on a central plane of the enclosing pressure vessel 3. The lower of these two edges rests in a bottom cradle 4 of which the top portions 5 (only one of which is shown in Figure 1) are of flat plate formation to receive one of the faces of the core structure

The cradle 4 has radial guides 6 which position it within the pressure vessel and the cradle is continued as a support structure 7 enveloping the core, radial guides 8 being provided at intervals around this support structure to position it.

Pressure pads 9 of approximately half the width of the faces of the core structure are provided at the four upper faces, these pressure pads being loosely linked together. Each pressure pad has a channel 10 within which runs a set of linked rollers 11, the links zig-zagging between the channel 10 and a cooperating track 12 on the support structure 7, as indicated in Figure 2. The linked rollers are in fact doubled as shown

to the right hand end of the core in Figure 2, the link and roller systems being in doubled lazy tongs construction, (but to the left hand end, and in Figure 3, only one set of linked rollers is shown for clarity).

The end rollers abut against a stop 13 which is welded to the support structure, and if axial pressure is applied at the end 14 of the link and roller mechanism pressure is applied between the supporting structure 7 and the pressure pads 9, this pressure being transmitted radially to the core structure. Relative movement between the support and the core face may thus be achieved as indicated in Figure 3, to take up shrinkage in the core structure.

As shown in Figure 2, the means for applying axial pressure to the link and roller mechanism comprises a pressure rod 15 extending through a shielding plug 16 which is contained within an extenson 17 from a standpipe 18 welded to the pressure vessel 3. The extension 17 is also fixed to the support structure so that the pressure applied to the link and roller mechanism is not transmitted to the pressure vessel.

At the outer end of the standpipe 18 a gas-operated piston 19 operates within the extension 17 to cause pressure to be applied to the end of the shielding plug 16 and thence to the pressure rod 15. Carbon dioxide under pressure is admitted to the chamber 20 behind the piston through a valve controlled inlet 21. An oil-operated ram 22 is provided to engage an extension 23 from the piston 19. Since the oil supply 24 for the ram 22 is pressurised by the carbon dioxide, the ram 22 is maintained in contact with the extension 23 by virtue of the head of oil from the supply reservoir 24; the valve 25 between ram and reservoir is a damper valve which permits of only a small rate of flow of oil therethrough. The ram 22 with its associated oil supply is duplicated, as shown, in case of failure.

Any oil which seeps past the rams is retained within the chamber 20 whence it can be drained at intervals through a drain plug 26, so that oil does not enter the core vessel. Also by ensuring that the operating pressure of carbon dioxide gas for the piston 19 is slightly higher than that of the gas within the pressure vessel it is ensured that activated gas does not leak past the piston 19. In order to take up pressure on the piston 19, for instance, while the gas system 21 is being serviced, an auxiliary high pressure oil supply is available under the control of the valve 27, the valve 25 being closed in these circumstances.

The functions of the gas-operated piston and of the oil-operated ram in each unit, of which there are eight around the upper four faces of the core structure, will be clear from the more general descriptions given above.

It will be evident that, in the particular structure illustrated in Figure 1, expansions and contractions of the core take place relative to the two faces of the core resting in contact with the bottom cradle 4, and that in the normal operating condition only the pressure pads on the vertical faces of the core are required to maintain the shape of the core for which purpose only relatively small forces are required. However the structure as a whole is capable of withstanding the shock loading referred to above.

In order that the core structure should not be subjected to an unbalanced force, the gas supplies 21 for the mechanism operating on the two vertical faces of the core are inter-connected, so that in the unlikely event of the gas supply failing there is no danger of a sideways force being applied only to one side of the core. For similar reasons, the supplies to the mechanisms for the other two top faces are also inter-connected.

One particular advantage of the mechanisms described with reference to Figures 1, 2 and 3 is that they may be withdrawn from the pressure vessel through the standpipe for servicing if necessary. Also by virtue of the linkage system, the bore of the standpipe need be only of reasonable dimensions since the linkage can be reduced in width by extension.

Especially where a core structure is formed of an assembly of vertical blocks, we have found that the present invention permits of a very satisfactory form of core structure. Thus in this form of structure, the blocks of the core are square in section and have their corner edges chamfered, to an appreciable extent, say ½ inch for a square of side 9 inches. When arranged in lines substantially end to end, these blocks will also be stacked as layers with all four faces of each block butting the neighbouring faces of other blocks. No structural connection is provided between each line of blocks, so that, with the exception of shearing forces transmitted across interfaces, each line is capable of transmitting compressive forces only. Such compressive forces induced by the restraint system according to the invention will then be sufficient to compact the core and to maintain it so, provided the chamfers prevent incompatibilities between the lines of blocks. In a further preferred modification each vertical line of blocks is made up of a group of lines of smaller blocks of which only the four corner lines have one lengthwise edge chamfered. Superposed blocks in each line will be spigoted, or otherwise interlocked, to the lower blocks, for example by a ball and socket type of joint.

The core with surrounding reflector is required to be housed within a supporting

structure and this supporting structure should be designed to give adequate resistance to the restraining systems operating on the core structure. For this purpose, the supporting structure preferably comprises a hollow cylindrical compartment, having reinforcing rings of suitable section spaced along and affixed to the exterior wall. In the particular example which is illustrated in the drawing accompanying the provisional specification in Application No. 13037/60, only the inner wall 31 of the cylindrical compartment is shown for simplicity.

The core comprises lines of graphite blocks 32 arranged also in layers each block having its edges chamfered as shown. Each layer of blocks is restrained between two members 33 which comprise rollers at each end of a pair of carriage bars 34 which have an extension bar 35 to a pivot 36. Only the rollers engage the side blocks.

Similar carriage bars 37 with rollers engaging the inner wall 31 of the supporting structure are provided and these also have extension bars to pivots 38. The pivots 36 and 38 are connected in alternation by pivoted links 39 and it is to be observed that if tension is applied to the end links 40, 41, the effect is to force the blocks 32 in each layer together by reaction at the wall 31. Adjustment of the force is effected by screw members 42, 43 anchored to brackets 44, 45 fixed to the wall 31.

The core structure, of which a vertical central section is shown in the drawing, will preferably be formed so that the reflector blocks surrounding the core proper will be shaped to give a perimeter to the core structure which is polygonal of side approximately equal to the width of the graphite blocks. It may then be desirable to arrange that the restraining forces applied by the restraint systems according to the invention are not applied in directions parallel to the directions of the lines of blocks, but it will usually be necessary to arrange that applied forces are substantially symmetrical about the axis of the core structure so as not to involve the development of a resultant distorting force on the core structure.

It is a feature of the type of restraint according to the invention that if one of the layers tends to sheer relatively to the next, the tensional link arrangement causes reaction on adjoining layers to resist such shearing movement. This type of restraint is therefore inherently stable, the mass of the core tending to resist the relative shearing of its individual layers.

It will be clear that the linkage shown in the drawing in Application No. 13037/60 may be tensioned by fluid-operated means functioning on the same principles as those illustrated in Figure 2. In this arrangement however pressure will be applied beneath suitable flanged heads on the end links 40, 41. A suitable follow-up system will also preferably be applied to enable the restraint to perform the same functions as that of the arrangement in Figure 2.

WHAT WE CLAIM IS:—

1. For an heterogeneous nuclear reactor of the kind comprising a core structure consisting of an assembly of blocks of moderating material, at least some of which blocks contain channels for the reception of fuel elements, said channels being substantially parallel to each other and to an axis of the core structure, restraining means for the core structure comprising a plurality of core-engaging assemblies spaced about the core, each said core-engaging assembly being adapted to exert a variable restraining force on said core structure in a direction substantially at right angles to said axis, and each said core-engaging assembly comprising a series of links between rollers or the like which are adapted alternately to engage the core structure, or means in contact with the core structure, and a support structure substantially surrounding said core structure, means being provided for exerting a force substantially parallel to said axis to cause said link assemblies to exert a variable restraining force on said core structure substantially at right angles to, and substantially towards, said axis.

2. Restraining means in accordance with Claim 1, wherein the core-engaging assemblies comprise link and roller systems in doubled, lazy-tongs construction.

3. Restraining means in accordance with either preceding claim, wherein the said force exerting means is arranged to operate to exert a tensional force on its said link assembly, so as to induce a compressive force against said core structure.

4. Restraining means in accordance with any preceding claim, wherein the said core-engaging assemblies are arranged in pairs, each pair being adapted to react against substantially opposite sides of the core.

5. Restraining means in accordance with any preceding claim, wherein said means for exerting said force substantially parallel to said axis is adapted for operation outside an enclosing vessel for said core structure.

6. A restraint system according to any preceding claim, wherein stress-varying forces are derived from a fluid-pressure-operated jack system.

7. A restraint system according to Claim 6, wherein the operating fluid for said jack system is identical with the fluid used for cooling the core of the reactor.

8. A restraint system for a gas-cooled nuclear reactor and as claimed in Claim 7, wherein said jack system is gas operated.

9. A restraint system for a gas-cooled

nuclear reactor and as claimed in Claim 6, wherein said jack system is hydraulically operated.

10. A restraint system as claimed in Claim 9, wherein the hydraulic supply for operating the jack system is adapted to be pressurised by a gas system whereby said hydraulic system functions as a follow-up to the gaseous system.

11. A restraint system for a core structure of an heterogeneous nuclear reactor of the kind wherein the core is formed as an assembly of blocks of moderating material, such as graphite, said blocks being arranged in substantially parallel lines of blocks substantially end to end, said lines of blocks forming layers in the form of rows of blocks, said restraint system being characterised in that it comprises a plurality of pairs of roller members, one pair for one row in each layer, the roller members of each of said pairs being arranged at opposite ends of the associated row, and linkage members associated with the line of roller members at each side of the core structure, whereby compressive forces may be induced in the rows of the layers by applying tension between the extreme ends of the systems of linkage and roller members, and whereby relative movement between adjacent rows of said moderator blocks in a said layer is permitted while at the same time linearity of said lines of blocks being substantially preserved.

12. A restraint system for the core structure of an heterogeneous nuclear reactor substantially as hereinbefore described with reference to Figures 1, 2 and 3 of the drawings accompanying the provisional specification of Patent Application No. 23468/59.

13. A restraint system for the core structure of an heterogeneous nuclear reactor substantially as hereinbefore described with reference to the drawing accompanying the provisional specification of Patent Application No. 13037/60.

14. An heterogeneous reactor comprising a core structure restraint system as claimed in any preceding claim.

For the Applicants,
F. S. PEACHEY,
Chartered Patent Agent.

Berwick-upon-Tweed: Printed for Her Majesty's Stationery Office by The Tweeddale Press Ltd.—1962
Published at The Patent Office, 25 Southampton Buildings, London, W.C.2, from which copies may be obtained.

376/285 Britain 916,144 Jan. 23, 1963

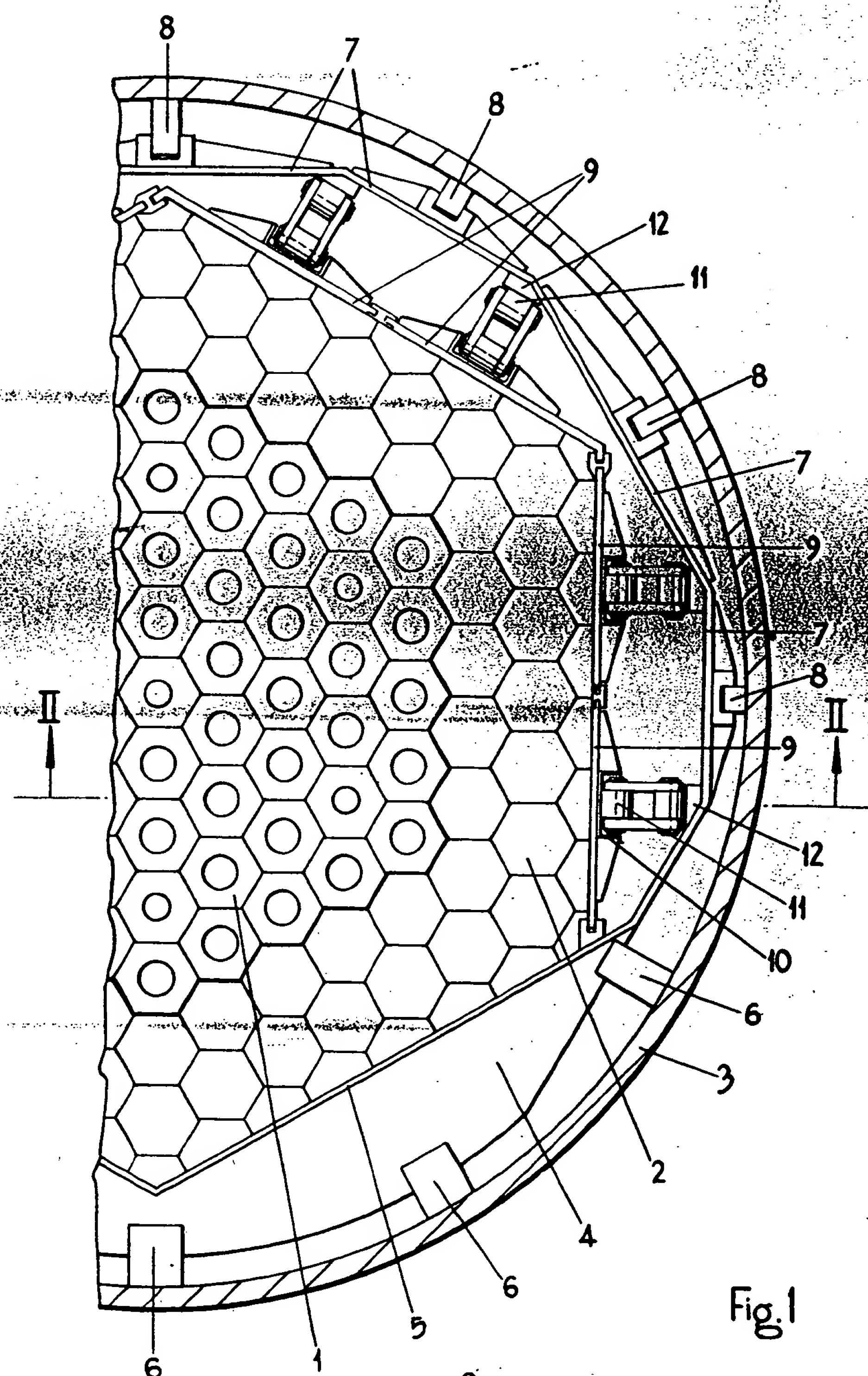


Fig.1

page 7
gas or
hydraulic

285

916,144 PROVISIONAL SPECIFICATION No. 23468/59
2 SHEETS
This drawing is a reproduction of the Original on a reduced scale.
SHEETS 1 & 2

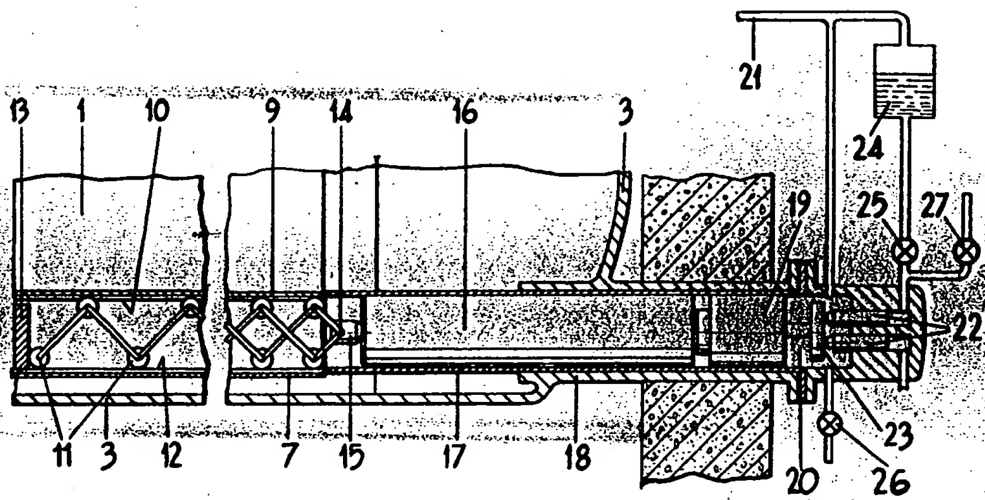


Fig. 2

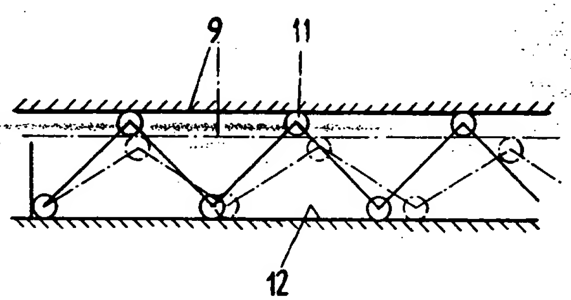
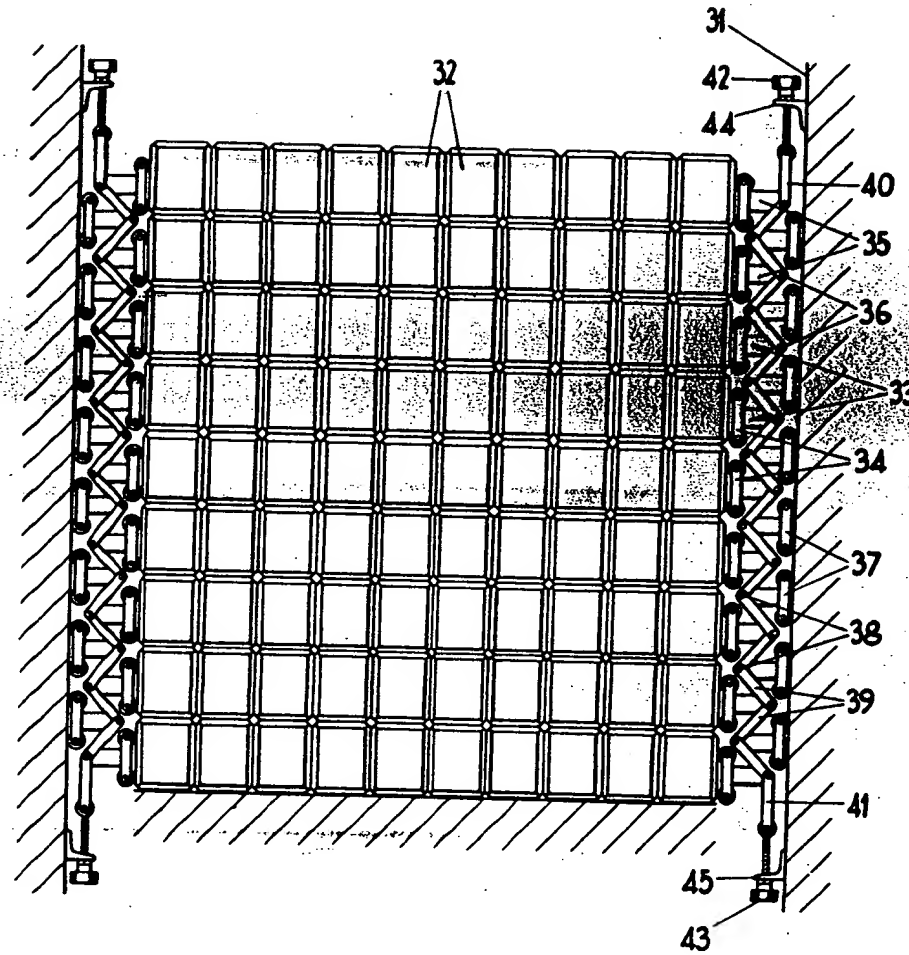


Fig. 3

916,144   PROVISIONAL SPECIFICATION No. 13037/60

1 SHEET   *This drawing is a reproduction of the Original on a reduced scale.*



916,144 PROVISIONAL SPECIFICATION No. 15211/59
1 SHEET *This drawing is a reproduction of the Original on a reduced scale.*

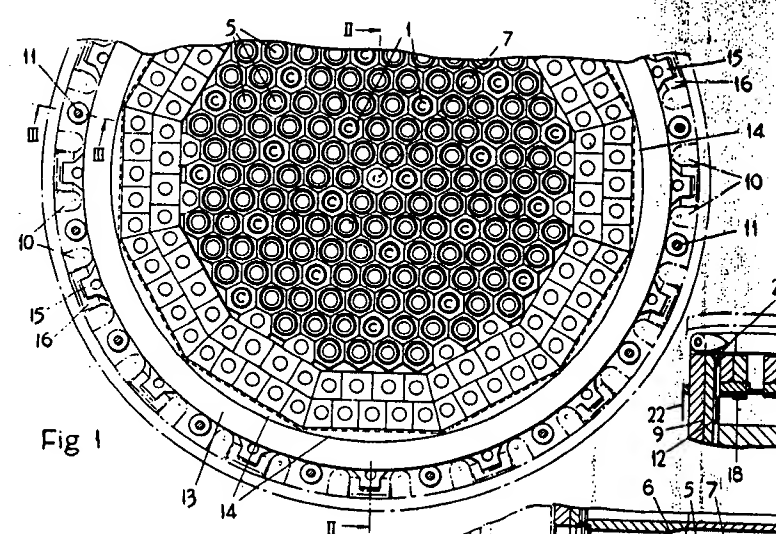
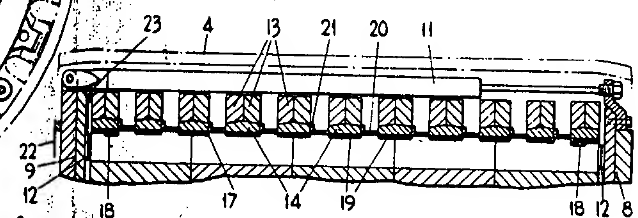


Fig 1

Fig. 3



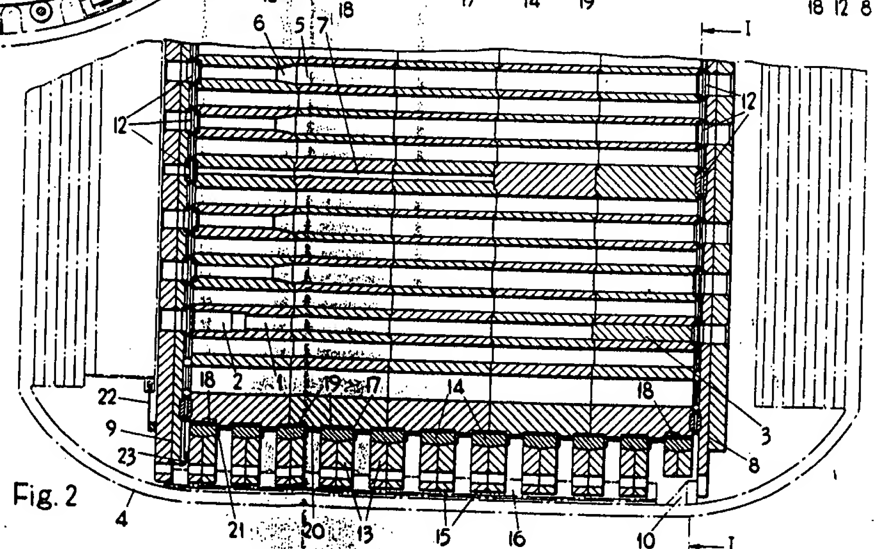


Fig. 2